COLOUR PHOTOGRAPHY FROM THE YELLOWKNIFE DISTRICT

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Of the many remote sensing techniques being practiced today, two stand out in their practical usefulness to earth scientists. One of these concerns the use of small scale aerial photography, the kind of photography taken from aircraft flying at heights of 40,000 feet or more. Large areas, up to 400 square miles, can be covered by a single photograph, at the present time and with available commercial equipment.

The second technique, the one which forms the basis of this paper, is aerial colour photography flown at altitudes of up to 10,000 feet. This paper provides examples of the kinds of information that colour photographs can show. The cost of obtaining aerial photography in Canada is also discussed.

Of course colour photography is not new. It is, however, a fast developing technology. Colour corrected lenses are becoming standard for all cartographic cameras. Faster films permit photography to be carried out at other than maximum sun angles and so the flying day is extended. And the introduction of automatic processing machines, and automatic dodging colour printers, will provide more even quality of output and hopefully will maintain the price of these services at a reasonable economic level.

In the summer of 1970, the GSC Skyvan aircraft flew a number of experimental surveys out of Fort Smith and Yellowknife in the Northwest Territories. Equipment consisted of a gamma-ray spectrometer, thermal infrared scanner, and a number of cameras which included a Wild RC8 cartographic camera. The colour photographs included in this paper were taken with this camera during the stay at Yellowknife.

Yellowknife is particularly suitable for photogeological studies because of the sparse nature of the soil and vegetation cover and because of the availability of geological maps of the area at scales up to 1:12,000 which provide very detailed ground control.

* Presented at the Symposium under the title "Getting Better Photography for Geologists".

In addition to this, colour photographs of the Canadian Shield have a certain rarity value, there being hardly any other examples on file in the National Air Photo Library in Ottawa.

The geology of the Yellowknife area is shown in simplified form in Fig. 1. Very simply the geology consists of a succession of pillowed and massive lavas, tuffs and agglomerates bordered to the west by a granitic complex and to the east by a series of metasedimentary schists and gneisses. The volcanic sequence was intruded at more than one period by a very large number of metagabbro and metadiorite dykes, sills and irregular shaped bodies. A detailed account of the geology is contained in the publication by Henderson and Brown, 1966.

The photographs used in this study cover a rectangular area approximately fifteen miles long and 3.5 miles wide elongated along the north-south trending granodiorite-volcanic boundary. Photographs were taken from three heights, 3,000 feet, 6,000 feet and 7,500 feet above average ground level providing average photoscales of 1:6,000, 1:12,000 and 1:15,000 respectively. As mentioned above, the camera was a Wild RC8 (9" x 9" format) with a 6" focal length lens. The film used was Kodak Ektachrome MS type 2448 developed to a negative. From the negatives, colour transparencies were prepared for stereoscopic examination.

The negatives will shortly be handed over to the National Air Photo Library in Ottawa. Prints of the illustrations can then be ordered directly from the library. The reproductions shown here are not of the same quality as the original transparencies but are included to demonstrate the features as they are described in the text.

Figure 2 is taken four miles north of Yellowknife. The white, cream and pink colours represent the western granodiorite

and the dark green and buff colours indicate the area underlain by volcanic rocks. Point 1 locates the West Bay fault which in this area has a sinistral displacement of about 3 miles. The Giant Yellowknife Mine at point 2 is one of the two gold mines still operating in this area. The margin of the granodiorite rocks is in places a fault and elsewhere is intrusive (point 3) into the volcanic assemblage. The granodiorite itself is variable in appearance. One form of the rock (5) is distinctly paler in colour and is ridged indicating the presence of a banded or strongly gneissic type of foliation. A second form of granodiorite (4) is often more pink in colour, does not have visible signs of foliation, and is evidently more resistant to erosion since it forms bosses of rather higher ground. The small nearly circular lake point 7, has a 300-foot wide rim of more resistant granodiorite. The origin of the lake has not been explained. A number of prominent gabbro dykes (6) are readily distinguished from the granodiorite even where individual outcrops are small as in the area immediately north of the circular lake. There is considerable iron staining in the host rock near the margins of the gabbro dykes and along the faulted edge of the granodiorite. This staining is not readily detectible on the black and white photography and because of the gradational nature of the staining is very difficult to map in the field. At point 8 a minor cross fault offsets a basic dyke. The banding in the volcanics shows particularly well at point 9 where cherty tuffs are interbedded with basalt flows.

Figure 3 is located immediately southeast of figure 2. The West Bay Fault (1) is again the dominent structural feature. The ore bodies of the Giant Yellowknife mine are located along shear planes (2) which can be recognized as areas of no outcrop. The sandy beach at 3 and the slime pond sediment at 4 are reminders of the ease with which non-vegetated surfaces can be recognized on colour photographs. The dark green volcanics west of West Bay Fault are lithologically identical to the buff coloured rocks east of the fault. The marked contrast in colour and resistance to erosion are due to differences in metamorphic grade. West of the fault the volcanics lie close to the intrusive margin of the granodiorite and are metamorphosed to epidote-amphibolite grade. East of the fault the volcanics lie about 3 miles from the eastward extension of the intrusive contact and are metamorphosed to green schist grade. The buff colouring of the volcanics is superficial but is enough to obscure many of the cherty tuff bands (5) and dacite dykes (6) that can be mapped so easily in the higher grade metamorphic rocks. Outcrops of porphyritic quartz dacite can usually be recognized by the distinctive pale yellow colour. Against the fault, however, the rock has a ferruginous stain and is difficult to separate from the volcanics. Quartzites of the Jackson formation (9) can be recognized by the scattered nature of the outcrop pattern by the fine laminations (bedding traces) visible on the outcrop and by the neutral grey colour of the rock. All of the rocks within a half mile radius of the Giant Yellowknife Mine are stained a darker shade than the rocks further away. The difference in colour is presumed to be due to the effect of gasses and particulate matter originating from the mine workings.

Figure 4 shows a portion of the volcanic sequence approximately two miles east of Ryan Lake at the northern limit of the photographed area. The main feature of interest here is the complex of quartz feldspar leucodacite dykes and irregular shaped bodies (1) which intrude the flows. Many shear zones (2) lie close to the strike of the volcanic layering. The volcanic formation contains numerous dykes and sills of metagabbro and metadiorite, most of which are practically identical in mineral content with the host rocks. The intrusions are very difficult to recognize in the field so it is hardly surprising that they can only rarely be recognized on photographs. Point 3 shows dark striped areas which represent metagabbro dykes. It has not yet been determined why the dykes can be recognized here and not elsewhere. Point 4 locates the workings of the abandoned Crestaurum Gold Mine. At point 5 there is an irregularly shaped outcrop of cream coloured cherty tuff which cannot be distinguished from the dacite intrusions.

Figure 5 is centered over Ryan Lake (1). Low domes of more massive and resistant pink-tinted granodiorite are shown at 2 and more foliated varieties at 3. At point 4 the rocks have a colour intermediate between that of the volcanics and that of the granodiorite. The published maps indicate that the area is predominantly granodiorite. A close inspection of the transparency shows many inclusions of volcanic origin. The rock here is clearly of mixed origin and quite different to the granodiorite west of Ryan Lake. The lesson to be learned is that it may be easier to map gradational boundaries on photographs than in the field. Point 5 indicates large diabase gabbro dykes clearly recognizable within the granodiorite because of the colour

difference and the wall rock staining. Within the volcanics, the gabbro can often be recognized by its red-brown tink and by the occurrence of scattered cream-coloured patches of lichen. At point 6 a pair of gabbro dykes each two to four feet wide can be recognized quite easily because of the contrast in colour with the granodiorite. Such dykes cannot be recognized where they intrude volcanic rocks.

Figure 6 is taken from a good quality 1:20,000 scale black and white negative from the National Air Photo Library and covers almost the same area as figure 3. The West Bay Fault, point 1, can be seen just as clearly here as on the colour photographs. The granodiorite too has a distinctive high reflectance and can be separated easily from the volcanics. Colour changes within the granodiorite cannot be recognized, nor can the ferruginous staining associated with the West Bay Fault (2) or with the margins of the diabase gabbro dykes (3). The gabbro dykes can be recognized by their lower reflectance and by the presence of cross joints but not nearly so surely as with the colour photographs. When outcrops are small and separated, recognition becomes uncertain. Point 4 indicates the area of darker rocks around the mine. The darkening effect on panchromatic film is rather subtle and would probably be missed on black and white film alone.

Figure 7 is centered on Lake Ryan indicated by point 1. North of Ryan Lake the granodiorite-volcanic boundary is clearly defined (2). South of the lake the boundary is far more difficult to recognize (3) where the difference in reflectance between granodiorite and volcanic material is obscured by a thin soil cover. Point 4 indicates an area with well defined contact against the volcanics and with a reflectance less than but fairly close to that of the granodiorite. From the panchromatic photography this area would probably be interpreted as granodiorite. From the colour photography (figure 5) the area can be recognized as a mixture of granodiorite and volcanic material. At point 5 a large diabase gabbro dyke is easily recognized by its darker tone and by the prominent jointing. At point 6 near the edge of the granodiorite intrusion, the dyke is reduced by local fracturing to a series of scattered outcrops. The cross jointing is no longer obvious and the normally low reflectance of the rock is obscured by soil so that the location of the dyke here is very difficult to determine. At points 7 and 8 diabase gabbro dykes lie in volcanic rocks and are difficult to recognize on this photograph. On the colour photograph of this area (figure 5) both dykes can be recognized.

ROCK RECOGNITION BY COLOUR

On fresh surfaces, Yellowknife rocks have a variety of colours ranging from white through pinks, browns and greens to black. Weathering effects are largely superficial in character but when combined with surface dust and rock fragments and organic material, particularly lichens and mosses, the range of rock colour exposed to the aerial camera is reduced to a significant degree. In turn, the range of colour actually recorded on aerial film depends not only on the camera system (lens plus filter plus film plus development) but also on the subject view angle, the elevation and azimuth of the sun and on the nature and path length of the atmosphere at the moment of exposure.

The effect of these many variables is that relative differences on the aerial photograph assume greater significance than absolute colour differences particularly with photographs taken at altitudes close to or higher than 10,000 feet. For this reason, Figure 8 is presented in tabular form indicating which of the rocks present in the area photographed can be distinguished from the surrounding lithology by differences in colour.

The remarkable feature of this table is the large number of rock units which in fact can be recognized in this way. The X's or failures in the main occur when gabbro intrudes gabbro, a difficult subject to map even in the field.

THE COST OF AERIAL PHOTOGRAPHY

Once the decision has been made to obtain new photography of an area, the question of the cost of colour relative to that of panchromatic photography becomes important. Comparative cost studies should be made regularly to monitor the advances being made in rapid processing and printing techniques. An exercise of this kind was undertaken in 1971 to cost colour and panchromatic photography for a reasonably large area, in this case the area covered by a 1:250,000 map sheet in the Yellowknife district of the Northwest Territories. This represents an area of 70 x 70 miles, or 4,900 square miles. A 9 x 9" format cartographic camera would be flown at 10,000 feet above average ground level

providing an average negative scale of 1:20,000. A flying height of 10,000 feet was chosen because this represents a reasonable upper limit for flying optimum quality colour. Unless the atmosphere is exceptionally clear, moisture and particulates in the atmosphere usually affect the colour balance of colour film at altitudes above 10,000 feet. The effect of light scattering by the atmosphere is to produce a yellow tint on the colour negative (blue on the print). This can be filtered out at the printing stage but only by reducing the range and brightness of colours reproducible by the print or transparency.

The main item is the cost of flying which is the same for colour as for monochrome photography. The cost of flying is estimated at $11.00 per line mile, a figure taken from the records of the Interdepartmental Committee on Air Surveys (ICAS), the group responsible for most of the Federal air survey contracts. Line mile costs could be higher for smaller projects or projects located in less accessible areas or for areas with less favourable weather conditions. Basic cost of the film, film development and reproduction is three to five times that for panchromatic material. For this exercise, the photography is needed for interpretation. The output is, in the case of panchromatic film, two sets of black and white paper prints. In the case of colour photography, the output is one set of colour transparencies for analysis in an office and one set of black and white paper prints (printed from the colour negatives) for use in the field. The result of the analysis is shown in Figure 9 which indicates that in these particular circumstances it would be entirely reasonable for colour photography to cost 34% more than panchromatic photography.

It is worthwhile comparing the cost of aerial photography with the cost of flying other airborne geophysical methods. Table I lists the average cost per line mile of a number of established airborne geophysical systems. Most of the survey systems quoted here are flown at low altitudes along closely spaced flight lines. Two to four line miles of survey are needed to provide adequate coverage for one square mile. Whichever way the figures are arranged, the cost of new photography is low compared with any other type of geophysical survey. One would not suggest that photography should or indeed could replace any of these geophysical methods but for the cost involved relative to the amount of information obtained it is surely not unreasonable for a geologist or mining engineer to insist on the provision of suitable aerial photographs to back up geological and airborne geophysical surveys.

CONCLUSIONS

1. Nine by nine inch format colour photography is in information value the cheapest and most effective remote sensing system available today.

2. By using colour negative film, colour transparencies may be printed for analysis in the office and black and white paper prints produced for use in the field.

3. With some notable exceptions, most of the features recognized on colour film can also be recognized on black and white photographs. Even so, coloured film is preferred because it permits the interpreter to recognize and understand information more rapidly and with greater confidence.

4. The cost of colour is still significantly greater than the cost of black and white photography. A particularly strong case for colour photography can be advanced in areas where there is a high percentage of outcrop and where photo scales of 1:20,000 or larger are acceptable.

5. Research work must be undertaken to improve the quality of colour photography taken at heights above 10,000 feet where moisture and particulates in the atmosphere affect the colour balance of aerial film.

REFERENCES

Henderson, J.F. and I.C. Brown:
Geology and Structure of the Yellowknife Greenstone Belt, District of Mackenzie. Geological Survey of Canada, Bulletin 141, 1966.

Henderson, J. B.
Stratigraphy of the Archaean Yellowknife Supergroup, Yellowknife Bay - Prosperous Bay Area, District of Mackenzie. Geological Survey of Canada, Paper 70-26, 1970.

Allen, S. J.
Geophysical Activity in 1969. Geophysics, Vol. 36, No. 1., February 1971.

TABLE 1. COST OF AIRBORNE GEOPHYSICAL SURVEYS IN CANADA

E.M.	*	$13.90/line mile
Combined E.M./Mag.	*	17.87 "
Magnetics	*	6.34 "
Radioactivity	*	7.15 "
AFMAG	*	15.00 "
High Sensitivity Gamma Spectrometer	#	17.50 "
Monochrome Photography		5.18/square mile
Colour Photography		6.86/square mile

*Taken from Geophysical Activity in 1969, S. J. Allen,
Geophysics, Vol. 36, No.1. Feb. 1971.

#Pers. Comm.

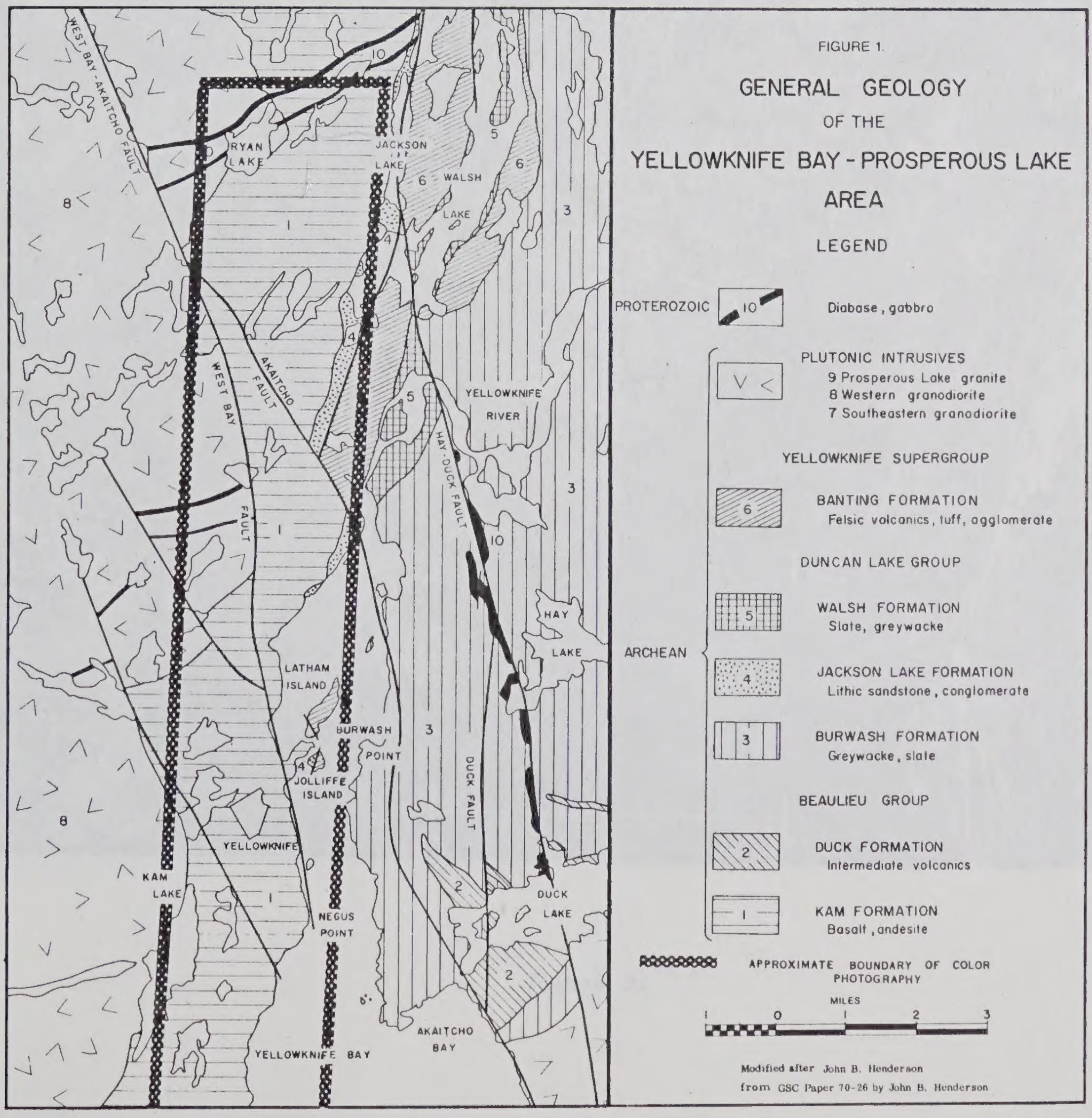


FIGURE 1.
GENERAL GEOLOGY OF THE YELLOWKNIFE BAY - PROSPEROUS LAKE AREA

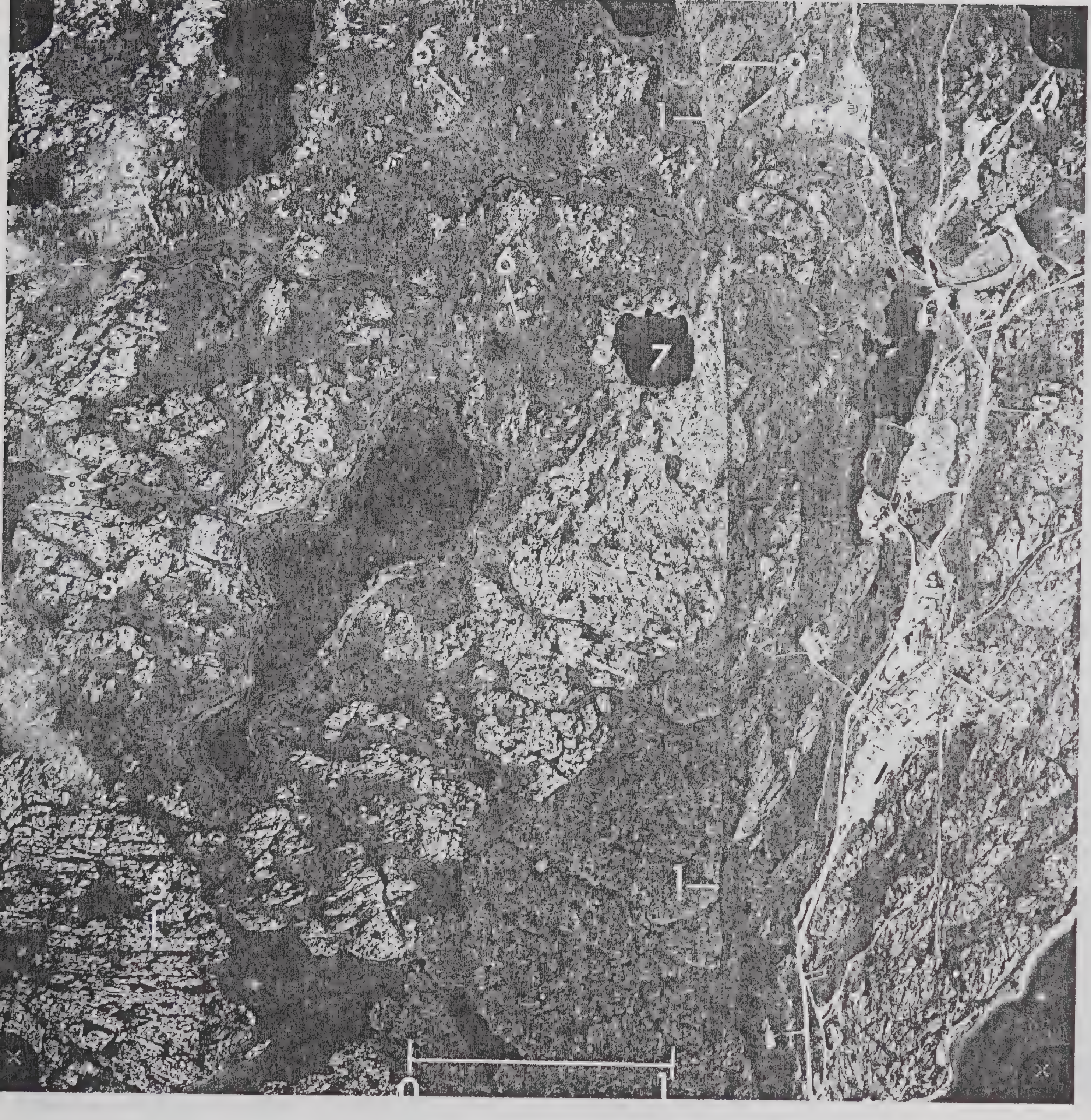


Figure 2.

Figure 3.

Figure 4.

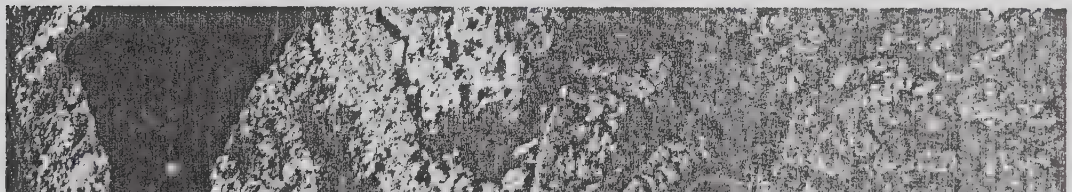


Figure 5.

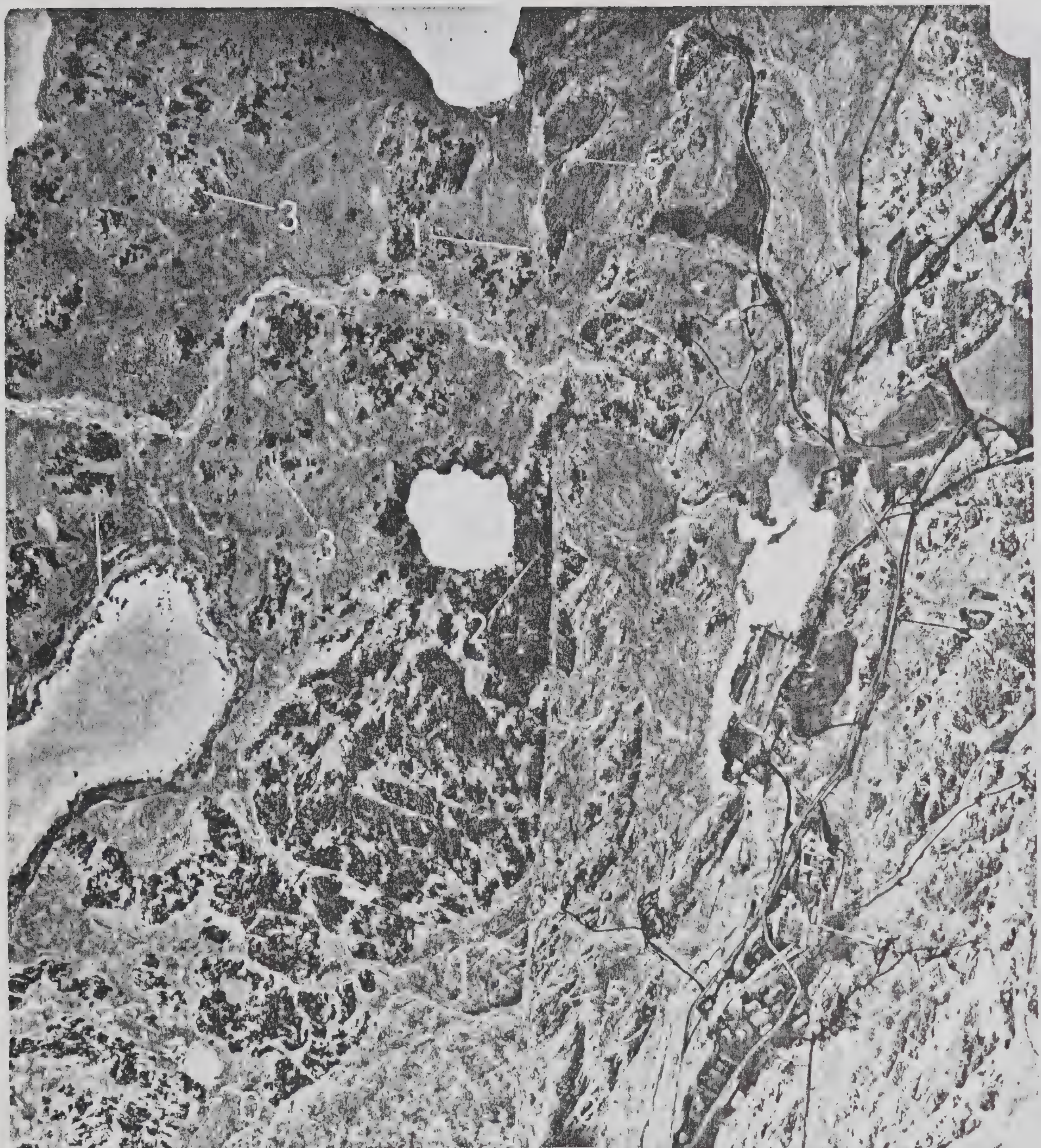


Figure 6.

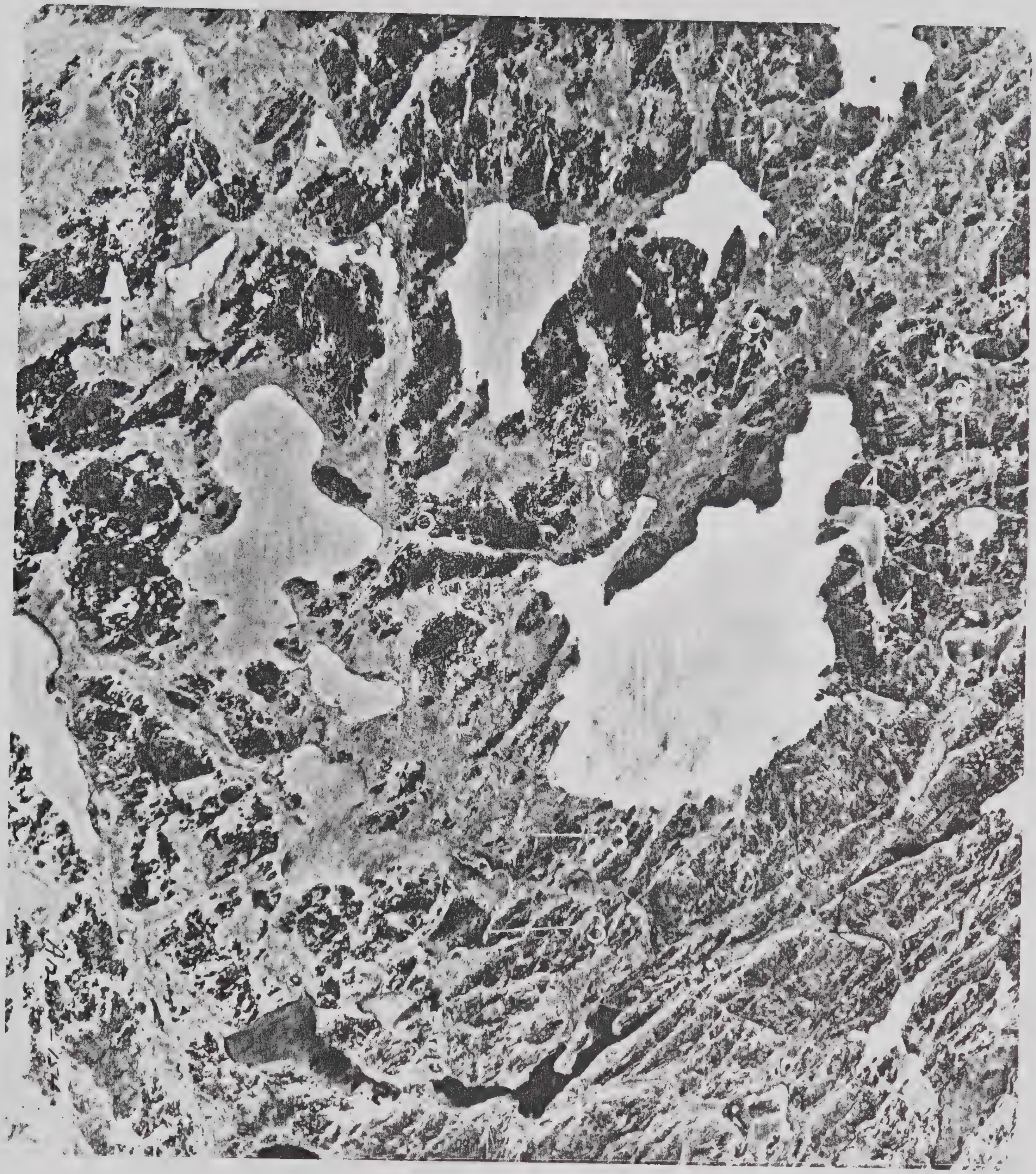


Figure 7.

YELLOWKNIFE COLOUR PHOTOGRAPHY

FIGURE 8

		14	13	12	9	8	7	3	2	1
QUARTZ VEIN	14									
DIABASE GABBRO DYKE	13	C								
GRANODIORITE	12	C	CT							
LEUCO-DACITE DYKE	9	C	C							
METAGABBRO DYKE	8	C	–	–	C					
METAGABBRO SILL	7	C	C	CT	C	X_C				
CHERTY TUFF	3	C	C	C	–	C	C			
DACITE TUFF	2	C	C	C	–	CT	CT	–		
GREENSTONES	1	C	CT	CT	C	X_C	X	C	CT	
		14	13	12	9	8	7	3	2	1

ROCK RECOGNITION

COLOUR	C
TOPOGRAPHY	T
ROCKS NOT SEPARATED	X
ROCKS NOT ASSOCIATED	–
COLOUR DIFFERENCE IN LOWER METAMORPHIC GRADE ROCKS	X_C

GROUND RESOLUTION

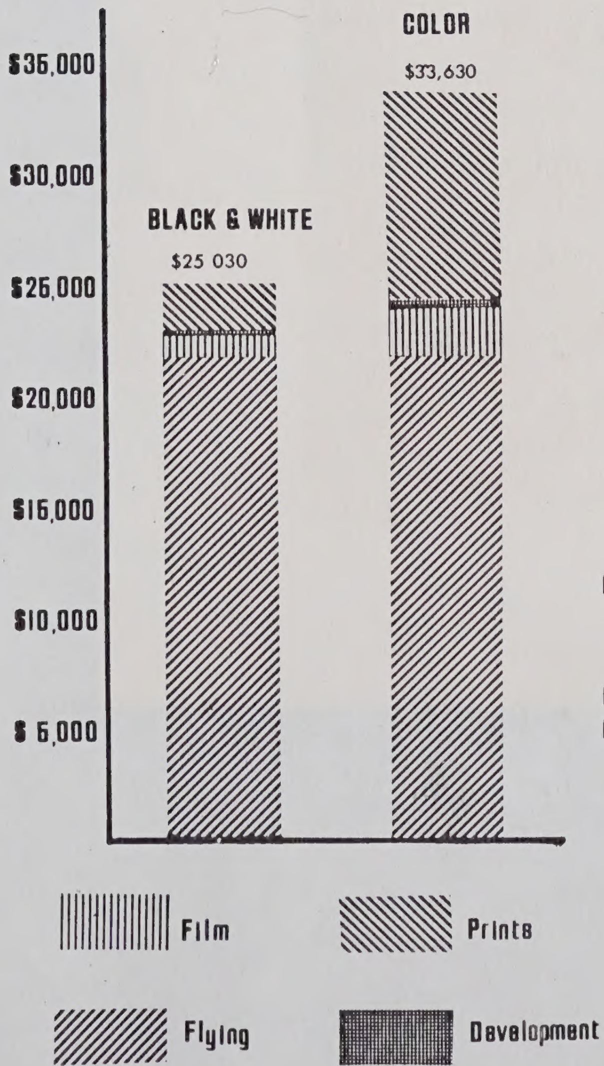
1:15,000 SCALE PHOTOGRAPHY

HIGH CONTRAST < 2 FEET

LOW CONTRAST 2-4 FEET

FIGURE 9

THE COST OF AERIAL PHOTOGRAPHY



AREA = 70 X 70 miles

= 4900 square miles

PHOTO SCALE 1:20,000

NO. OF LINE MILES = 2170

NO. OF PHOTOS = 1922

B.+W. PHOTOGRAPHY = $ 5.18 sq. mile
(2 sets paper prints)

COLOUR PHOTOGRAPHY = $ 6.86 sq. mile
(1 set Colour transparency)
(1 set B.+W. paper prints)

Colour costs 34 per cent more then B.+W.